Remarks

The reply is being filed concurrently with a request for continued examination to secure entry of the foregoing amendments. By way of the foregoing amendments, withdrawn claims 1-6 have been cancelled along with claims 7-16, claims 17-19 and 21 have been amended, and claims 31-40 have been added. Accordingly, claims 17-40 remain pending in this application.

As amended, claim 17 recites a device for heat treating an extrusion block immediately before it is fed into an extruder, comprising a heating device configured to heat the block to an elevated temperature; and a cooling device configured to receive the heated extrusion block in a stationary horizontal orientation in a spraying area having a horizontal axis The cooling device includes cooling fluid spray nozzles for rapidly cooling the stationary heated extrusion block. The spray nozzles surround the spraying area and have axes directed radially inwardly in relation to the horizontal axis of the spraying area. In addition, the spray nozzles are arranged in groups axially disposed along the horizontal axis of the spraying area, and the groups of spray nozzles are sequentially switched off while the block is held axially stationary relative to the spray nozzles.

A device as set forth in amended claim 17 is neither disclosed nor suggested by Biswas et al. In the Biswas et al. device, the block 10 is maintained in a vertical orientation within the chilling chamber 5. Moreover, the block is moved through the chilling chamber while being sprayed with a coolant. Consequently, there is no disclosure of axially disposed groups of spray nozzles being sequentially switched off while a horizontally disposed block is held axially stationary relative to the spray nozzles.

Visser et al. was cited to show that a metal extrusion billet can be horizontally cooled by a plurality of spray rings in order to create a temperature gradient. Initially it is noted that one skilled in the art would not be motivated by Visser et al. to reconfigure Biswas et al. in a manner that would give rise to a device as set forth in amended claim 17. Any such modification would result in the device of Biswas et al. no longer operating in its intended manner, i.e., that of maintaining the block vertical as it moves through a chilling chamber.

Even if the skilled person were somehow motivated by Visser et al. to modify the Biswas et al. device by reorienting the chilling chamber horizontally instead of vertically,

the result would still not provide a device as set forth in amended claim 17. Visser et al., like Biswas et al., moves the billet through the spray ring during cooling. According to amended claim 17, the block does not move relative to the spray nozzles during cooling. This difference overcomes problems associated with the devices of Biswas et al. and Visser et al., such as the need for a complicated control of the billet movement. For a further discussion of the invention vis-a-vis the prior art, enclosed is a copy of a presentation given by the applicant at a conference in Rome in March 2003.

For at least the foregoing reasons, claim 17 and the claims depending therefrom are submitted as being allowable over Biswas et al. and Visser et al.

Newly presented claims 31-40 are presented for favorable examination. In view of the foregoing discussion of Biswas et al. and Visser et al., the Examiner presumably will also appreciate that these claims are allowable over said references.

Conclusion

In view of the foregoing, request is made for timely issuance of a notice of allowance.

Respectfully submitted,

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THERMAL PROCESSING OF LOGS AND BILLETS BEFORE EXTRUSION

Carl Kramer*, Bruno Mancini,**

ABSTRACT

The paper describes a novel thermal processing of logs and billets before the press. It consists of a heating to an elevated temperature which can be kept constant for most AA 6 xxx alloys, followed by an individual billet quenching. The first part of the heating up to about 460°C is carried out in a conventional direct gas fired rapid heater. The final heating is executed without any danger of partial melting in a novel convective heater which guarantees a perfect temperature homogeneity in the billet. Before loading into the press, what means if logs are heated before hot shearing, the billet is transferred into a stationary billet quench. In this quench the billet temperature is reduced to the optimal extrusion temperature for the alloy and for the relevant extrusion process considering extrusion ratio and optimal extrusion speed. Furthermore by the quenching a process optimized temperature taper is generated.

The novel process can contribute significantly to an increase in extrusion productivity and also help to solve the billet heating problem at "small lot production" without expensive inductive heating.

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INTRODUCTION

The heating process of logs and billets before the press is of great importance for the productivity of a light metal extrusion plant. The heating should be fast and uniform and the heating device should adapt the heating procedure without significant temperature fluctuations to the billet frequency or to stops of the extrusion process, e.g. when changing a die. Furthermore the heating should allow the so called "iso-thermic" extrusion and should be able to supply the billets for all possible extrusion shapes and characteristics always with the optimal temperature, which leads to the extrusion temperature for the highest possible extrusion speed and the best quality of the profiles - especially of the profile surface. Reaching this rather demanding aim is an important contribution to solve the well-known "small lot problem". In order to come closer to this ideal situation, conventional billet heaters are frequently combined with so-called "taper-heaters" which superimpose to the more or less uniform longitudinal temperature distribution in the billet, when leaving the heater, a temperature profile decreasing from the frontal surface to the end surface of the billet. This temperature taper leads for a certain extrusion rate and speed and hence a defined input of billet transformation energy to an extrusion temperature which is constant during the entire extrusion process. The taper heaters are usually operating electrically by induction heating. Because of the rather high cost for investment and operation the industry tried in the last years to substitute the taper heating by taper quenching. In these taper quenches usually the billet is moved through a cooling system consisting of water spray nozzles. The complicated control, however, and the lack of accuracy and repeatability may be the reasons why the taper quenching process up to now did not yet find wider application in spite of the fact, that no expensive electric energy consuming installation is required.

THE BILLET HEATING

Due to high specific heat capacity of aluminium of 1 kJ/(kgK), in comparison to about 0,4 kJ/(kg/K) for copper and steel, high production billet heaters are usually gas fired. In rapid heaters, the flames of the gas burners come in immediate contact with the billet surface. Local overheating or spot melting, especially of low melting eutectica in the material matrix, and considerable temperature uniformity are the well known problems of this kind of heaters. In order to exclude this disadvantages but to keep the advantages as simple function and high heat-up rate, it is favourable to combine a conventional billet heater with a so-called convective billet heater [1], which is installed at the end of the heating device. In a convective heater [2], the billets are heated by strong jet impingement of hot gas which is recirculated in the individual convective billet heater zones by powerful hot fans. The recirculated gas, usually hot air, is heated by burners preferably recuperative burners. Figure 1 shows a schematic of such a combined heater and Figure 2 a photography of a production plant. Because the billet cannot become hotter than the air temperature, overheating is absolutely excluded by the selection of the right set point temperature of hot air recirculation. The strong recirculation and the high convective heat transfer contributes in addition to a excellent uniformity of the

temperature distribution. A temperature homogeneity related to a billet diameter of 200 mm of about +/- 5 K can be achieved easily. It is advantageous to install two convective billet heater zones - one behind the other - at the end of the combined heater, so the first zone can be operated with a higher air temperature to execute the final heating. In the second zone, the gas temperature will be close to the desired final billet temperature, so that in this final heater the billet will be always kept at the same temperature, regardless changes in throughput or even a press stop.

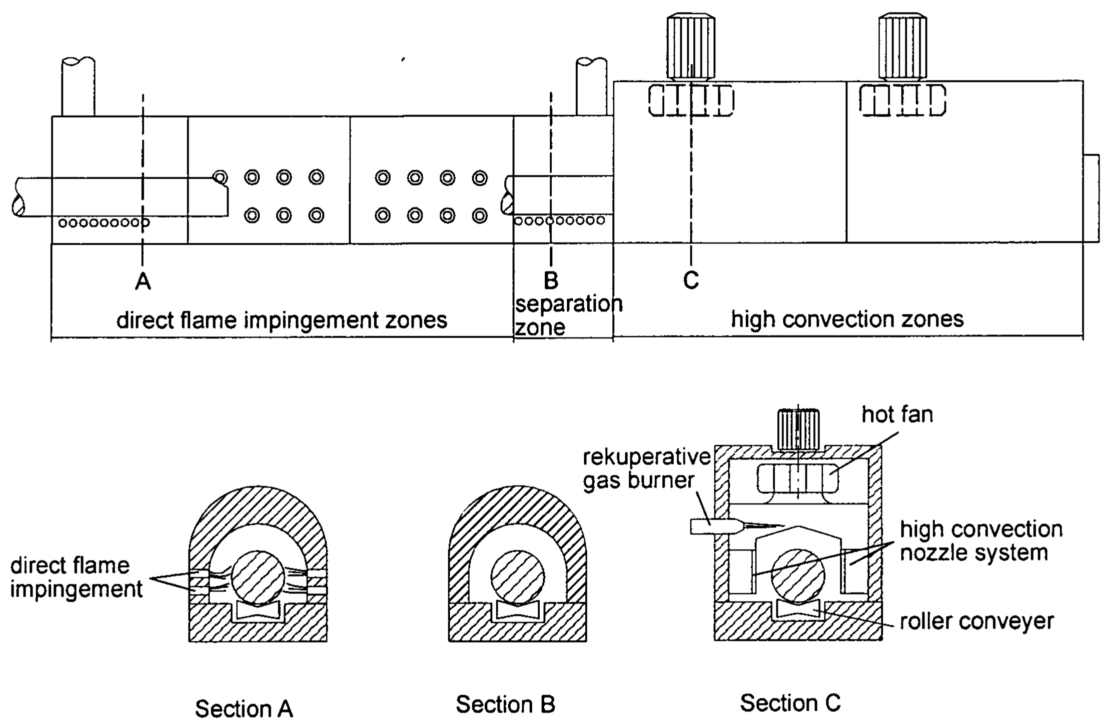

Figure 1: Schematic of a combined billet heater according to [1] consisting of a part with heating by direct flame impingement and a part with high convection heating

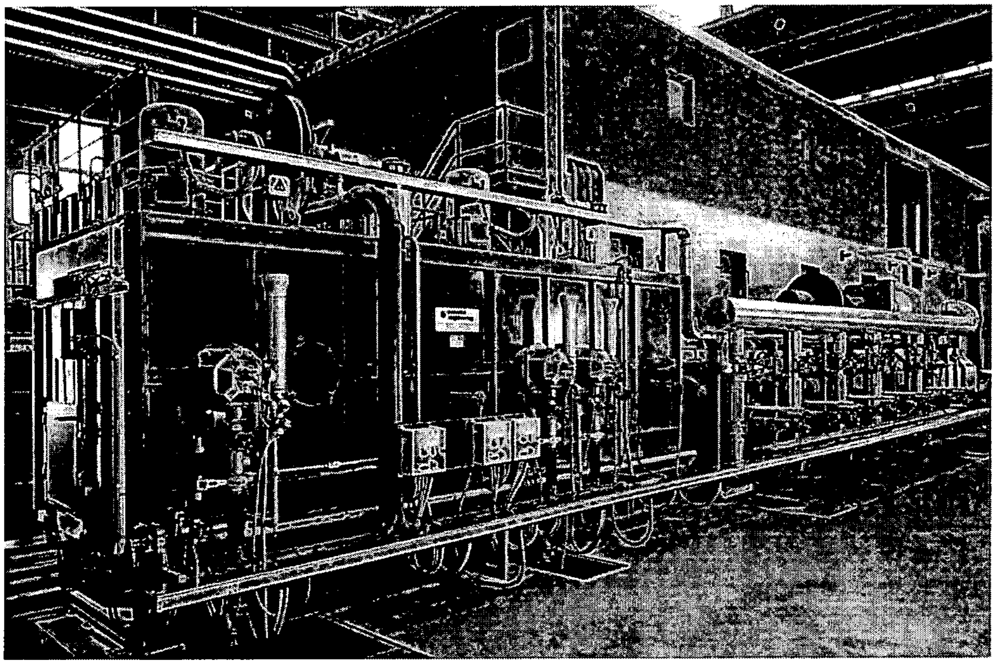

Figure 2: Combined billet heater (left: high convection, right: direct flame impingement)

COMBINATION OF BILLET HEATER AND BILLET QUENCH

Beside the exit of combined billet heater, a billet quench is installed, Figure 3. This billet quench consists of one chamber for cycle times of about 1 minute and more. For shorter cycle times, e.g. 45 seconds, two quench chambers are necessary in order not to delay the delivery of billets to the press due to the necessary temperature equilibration time. Figure 4 shows a billet quench in "twin array". The billet quenches [3] are operating stationary. That means, there is no relative movement between billet and quenching device during the quenching process. Therefore no complicated combined control of billet movement and quenching intensity is required. Various spray rings arranged over the length of the billet. It is favourable to divide these quench rings into an upper and an lower part in order to compensate the influence of the gravity which is different above and below the equator of the billet. By the right control of the spraying time of the individual spray rings and the appropriate design of the nozzle array of the spraying system, it is possible to achieve an effective and reproducible taper cooling. A computer program - taking into account the thermal properties of the billets defined by the billet material and billet dimensions - cares for the optimal control algorithm. Figure 5 gives an example. The maximum temperature taper $\Delta\vartheta_{billet}$ related to a billet length of 1 m is more than 200 K. After a rather short quenching time, the taper is generated in the following temperature equilibration time. This temperature equilibration time includes the time necessary for the transfer of the billet out of the quench into the container of the press. Temperature equilibration takes place mainly in the cross section of the billet. The reason for this is obvious by considering the Fourier-equation for

temperature equilibration. This equation teaches that the speed of temperature equilibration is reduced inversely to the square of the distance over which the temperature equilibration takes place. That means that a billet of 200 mm diameter and 1 m length, which has a distance for temperature equilibration of half the diameter in radial direction and 1 m in length direction has a $(1000\ \mathrm{mm}/100\mathrm{mm})^2 = 100$-times faster temperature equilibration in the cross section compared to the length. Therefore, the temperature taper impressed over the length of the billet remains nearly unchanged during the short time span which is necessary for a sufficient temperature equilibration over the billet cross section and the transfer into the press.

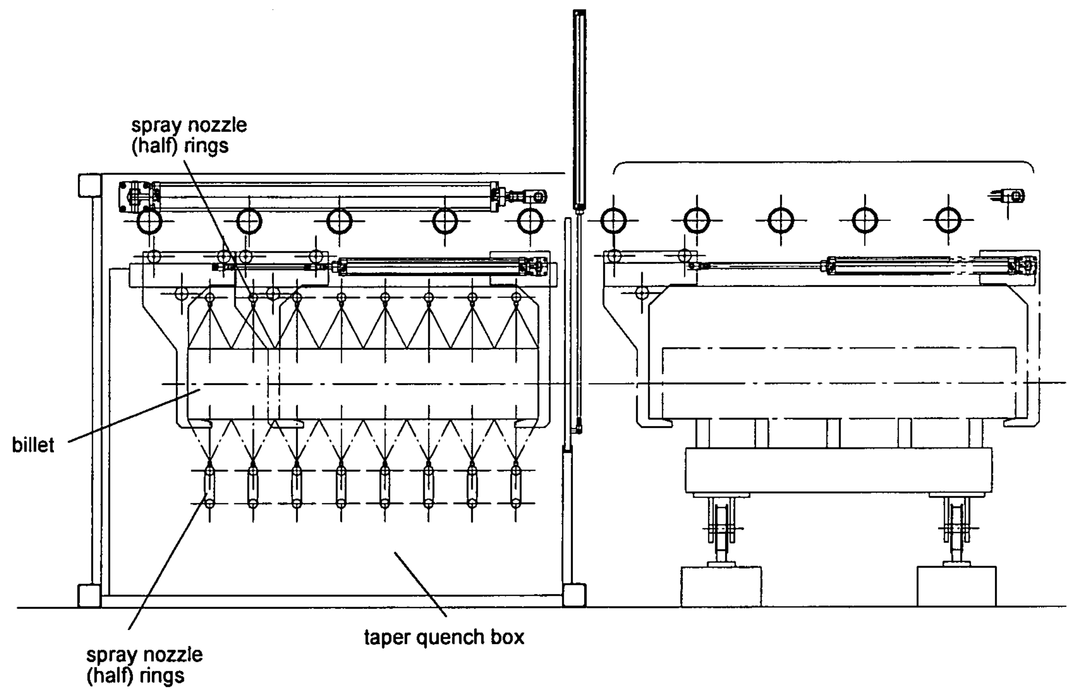

Figure 3: Schematic of a stationary taper quench according to [3]

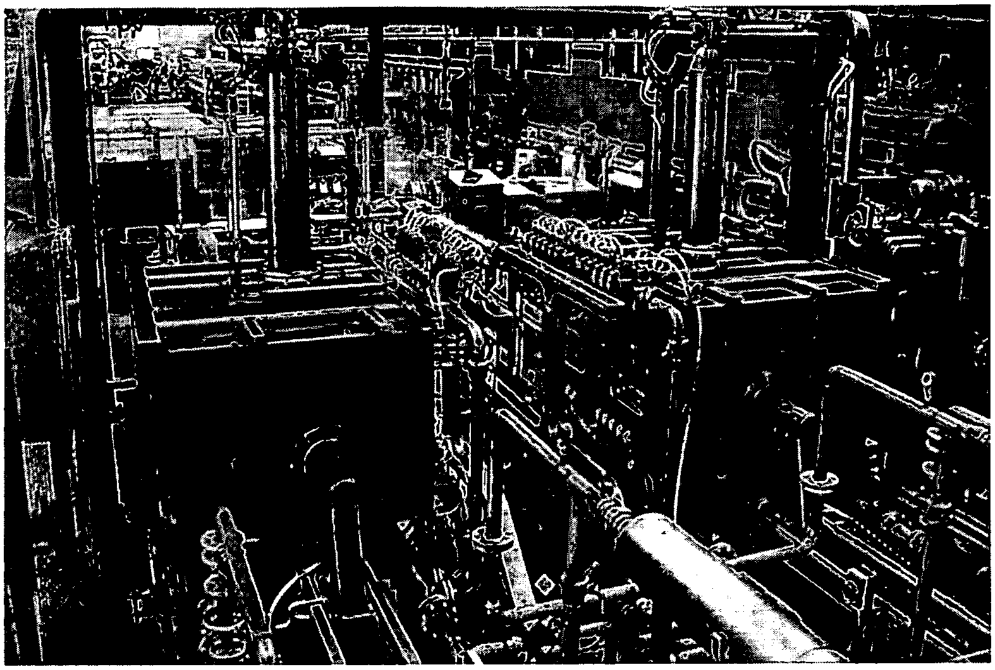

Figure 4: Taper quenches in "twin array"

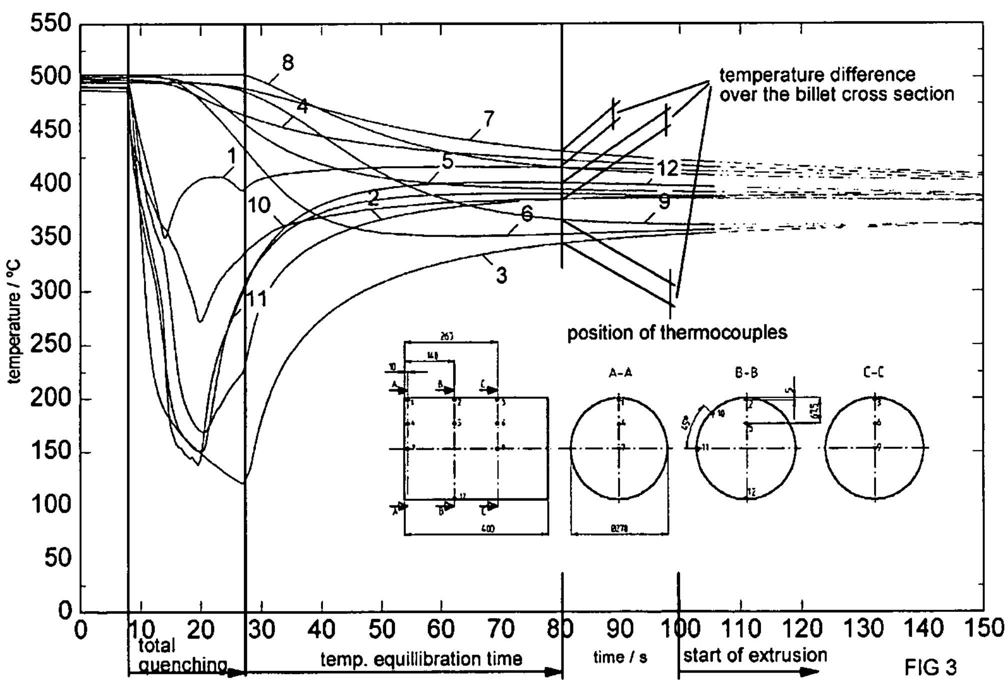

Figure 5: Results of temperature measurement at various billet positions in a taper quencl ding to Figures 3 and 4

The billet quench does not only allow the production of a taper, but also a general reduction of the billet temperature which may be necessary, if an extrusion with a high degree of transformation and accordingly high generation of transformation heat has to

be extruded. So the combination of the novel combined billet heater with the reliably and efficiently controllable taper quench enables the operator to select as a set point temperature for the material the maximum billet temperature which may be necessary for optimal extrusion of the simplest extrusion with the lowest generation of transformation during the extrusion process. By linking the process control of the press with the process control of the heater and the quench it is therefore possible to have always optimal extrusion conditions for all kinds of profiles which occur during the production even billet by billet This leads to a significant increase of the average production and indicates that by rather simple installations the productivity of extrusion press can be considerably increased.

PRODUCTION EXPERIENCES WITH THE COMBINATION OF BILLET HEATING AND BILLET QUENCHING

Production experience in various extrusion plants operating with the new taper quench described, showed that the extrusion speed for alloys 6xxx can be increased for about 10 % compared with the state of the art situation.

When combining the new taper quench with the described billet heating method the increase of productivity is far higher. Some results are given in the table.

	taper quench only	overheating + quenching + taper quench
billet temperature, front	480 °C	545 °C
billet temperature, end	270 °C	270 °C
taper temperature difference	210 °C	275 °C
profile temperature at die exit	560 °C	560 °C
specific break through pressure	550 MPa	> 750 MPa
extrusion speed	27 m/min	46 m/min
profile surface quality	acceptable	excellent and constant

The data given relate to: ~ 4000 tons press, an alloy 6060 profile of 1.4 kg/m, a billet length 1300 mm, a billet diameter 354 mm, and a die with 1 cavity.

The increase of extrusion speed is enormous. The reason for this is that brittle phases occurring in AlMgSi alloys and forming rather large precipitations in the material matrix at usual extrusion temperatures, which are limiting the possible extrusion speed,

are at least partially resolved and reduced in size and number by fast cooling from a somewhat elevated temperature to the final extrusion temperature.

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